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## Relief of a Morainal Zone of the Linné Glacier (West Spitsbergen)

Rzeźba strefy marginalnej lodowca Linneusza  
(Spitsbergen Zachodni)

Рельеф маргинальной зоны ледника Линнея (Западный Шпицберген)

### INTRODUCTION

The Linné Glacier (Linnébreen) is located in the southern part of the Linnédalen, Nordenskiöld Land. Its position is defined by the latitude 77°58'N and longitude 13°56'E. A morainal zone of this glacier was investigated that is the area of about 2.6 km<sup>2</sup>.

Fieldworks focused on glacial deposits and relief of the morainal zone. Some attention was also paid to the retreat rate of the Linné Glacier and melting of the buried relic ice as well as to periglacial processes. Basing on the analysis of areas with ice-cored moraines and on the other changes during a retreat of this glacier, the successive development phases of the morainal zone were described. Fieldworks were mainly based on geomorphologic mapping with a use of the topographic map prepared by a plane method by the topographic group (Horodyski, Lewandowska, Malanowski, 1981). The mapping was also facilitated by the map in a scale of 1 : 25 000, being the enlarged fragment of the Norsk Polarinstitut map (Topografisk Kart over Svalbard, 1 : 100 000, 1948).

Fieldworks were carried through from 29th July to 5th September 1980 during the II<sup>nd</sup> Geography Students' Polar Expedition of the Warsaw University.

### DESCRIPTION OF THE GLACIER

The Linné Glacier is surrounded from the west and south by the Linnefjella massif (with the Systemafjellet peak, 744 m a.s.l.) and by the Christenfjella massif (680 m a.s.l., Phot. 1) from the east. A long axis of the upglacier and midglacier sections runs from south-south-

west to north-northeast and downglacier from south-southeast into north-northwest (Nordenskiöld Land — Touring Map, 1979). This change has been caused by a transfluence in the past, just in this place, of the Aldegonda Glacier and two glacierets at slopes of the Christensenfjella in the east (Musiał 1981). The glacier is now about 3 km long and occupies an area of 2.83 km<sup>2</sup> (Smoleński 1981). A regional snowline, calculated by the Hess's method (Bogucki, Musiał 1979) is located at 335 m a.s.l. W. Smoleński (1981) found during five-week long measurements along transversal sections in summer 1980 that the Linné Glacier was not moving at all.

Above the snowline there are four glacial cirques. The glacial tongue slightly sloping eastwards, its snout is flat and considerably covered by a surface moraine and wide median moraines (Phot. 2). Such a gradient of the tongue is to be explained by a quicker ablation of the right flank due to a full solar exposure during the greatest insolation. In the same time the left flank of the Linnébreen remains in shadow of the massif 668 m a.s.l.. The whole surface of the glacier is drained by dense network of supraglacial streams and two lateral rivers. The upper parts of cirques are bordered by bergschrunds and contain systems of transverse crevasses (Phot. 1).

Basing on the classifications of Shumskyi (1949) and Troitskyi (1975), the Linnébreen belongs to the valley subtype of mountain glaciers whereas it is to be considered to be a dead glacier in the classifications of Ahlmann (1948). It is most close to the subpolar maritime glacier of high latitudes in the classification of Baranowski (1977).

A geological structure of the Linné Valley indicates a chronological succession of rocks and a meridional zonality of their occurrence, from the oldest ones in the west to the youngest ones in the east (Gogołek, Lewandowski 1980).

## DESCRIPTION OF A MORAINAL ZONE

### ICE-CORED MORAINES

In the investigated morainal zone there are lateral and terminal ice-cored moraines.

The outer terminal ice-cored moraine is from 80 to 150 m wide and considerably high, to 33 m (Phot. 2). Distal slopes are quite steep (to 35°) if compared with gentle proximal slopes (to 15°). The outer moraine is composed of surface glacial drift, from 0.5 to 1.5 m thick, that protects the ice core from melting (Ryżyk 1983). It is composed of a vari-grained matter but in many places there are concentrations of a coarse material to 1 m in diameter. Rock debris and boulders are slightly rounded. Locally they are also well rounded. The highest elevations of terminal moraines occur at the contacts with median moraines. A similar regularity was also noted by Szupryczyński (1963) in morainal zones of the Gas and Werenski old glaciers of South Spitsbergen.

A natural exposure of the outer terminal moraine enables to study the beds of the inner moraine (layers dip  $30^\circ$  northwards), separated from one another by patches of relic ice (Phot. 3, 7). They are the shear planes, along which a mineral matter moved out from the inside of the active glacier. During the glacier stoppage this rock debris spilt in places where shear planes are cut by the glacier surface, and formed a small debris ridge at the foot of distal slopes. A small volume of sediments proves a short stoppage of the glacier. A similar situation was noted at the edge of the Barnes Glacier, Baffin Land (Word 1952; John 1953) and in Greenland by Møller (1960) and Schytt (1956) vide (Szupryczyński 1963). The terminal ridge of the Linnébreen is to be defined as the shear plane moraine. Dipping of layers of a mineral matter and of the ice northwards corresponds with the previous direction of the glacier movement. Such phenomenon is very rare. It should be connected with a morphology of the substrate of the morainal zone. The western ice-cored moraine was mostly formed along a roche moutonnée composed of Carboniferous rocks. In the north this moraine covers vestly a ridge of quartz sandstones. In the central depression of the morainal zone there are numerous outcrops of the bedrock. They prove a small thickness of a ground moraine and the further continuation of the ridge. During the glacier advance its snout must have passed over this obstacle. The ridge was already considerably lower here than in the west. The tongue of the Linnébreen (supplied from the east by the Aldegondabreen) was, after taking the obstacle, inclined northwards what is preserved in the inner structure of the outer ice-cored moraine.

Terminal moraines of the neighbouring glacier are different and are considered to be push and depositional ones (Szupryczyński 1968).

An inner ice-cored moraine is located within the morainal zone. It is about 25 m high and from 50 to 100 m wide, and occurs 200—300 m far from the crest of the terminal moraine (Fig. 1). Small solifluction tongues at its proximal slopes make the exposures of the ice core, capped by a till.

Terminal ice-cored moraines are cut by the Linné Stream that drains the whole morainal zone (Phot. 3). The outer moraine has two river gorges whereas the inner one has four gorges that are inactive at present but only modelled by solifluction. Locally the area is entered by pioneer plants: mainly saxifrages and lichens.

Lateral ice-cored moraines run at both sides of the glacier, being from 210 to 330 m wide and to 60 m high (Photos 1, 2, Fig. 1). They appear in the nival stage where a weathering waste is stored. The cirque slopes are steep rocky walls, at which the nival-corrasion chutes are used by a weathering waste to get onto the firm fields (Phot. 1). Some waste enters the transverse crevasses and the bergschrund, thus feeding the shear planes. The rest of the weathering waste forms the lateral moraines. The weathering waste is subjected in the nival stage to the intensive frost weathering what makes it to be angular. In the subnival stage, there are locally, amidst the angular debris of lateral moraines, the well rounded boulders as the effect of glacial erosion.

Therefore, a slight mixing occurs of the debris from the glacier inside and the weathering waste from the nival stage.

At the eastern lateral ice-cored moraine and to a smaller degree, at the western one there are numerous flow tongues. During a polar day the proximal slopes of the eastern moraine are well exposed to insolation whereas they remain for a longer time in shadow at the western one. A thawing is deeper at the better exposed slopes and reaches the relic buried ice under a till so, long and wide mud streams are formed (Photos 1, 2). The largest feature of this type is about 150 m long and the niche occupies an area of about 3000 m<sup>2</sup>. Solifluction and thawing result in most significant morphologic transformations in some fragments of ice-cored moraines.

Both ice-cored moraines are covered at long distances by long and parallel furrows, from 20 cm to 5 m deep. The deepest reaches of the furrows are well accentuated by snow, preserved there during the whole summer of 1980. Such features have been probably formed due to linear melting of relic ice with a small content of inner and surface moraine.

Rock beds in the Linné Valley run meridionally. At surfaces of terminal and lateral ice-cored moraines there are, long and parallel to one another and the glacier axis, streaks of a rock debris. Their colour is different as the source material of the streaks has been transported without any mixing by the glacier ice to the morainal zone or just directly from the mountain slopes to the lateral moraines. Thus, the transport route of this debris can be defined (Musiał 1983).

#### ZONE OF GROUND AND ABLATION MORaine

In the morainal zone of the Linné Glacier there are areas with flat and hummocky ground moraine (Fig. 1). The ground moraine, 0.3—1.0 m thick is primarily frozen to the glacier sole what is exposed at dead ice blocks, that are separated now from the glacial tongue. In this bed the mineral material is usually oriented meridionally (Phot. 4). In result of ice melting a ground moraine, to 2 m thick, is entirely exposed and its surface is covered by an ablation till, being formed from the surface moraine. But in the forefield of the glacier there are also the places with bedrock outcrops, exposed due to erosion of lateral streams.

The inner ice-cored moraine and the glacier snout is separated by a flat ground moraine whereas between both terminal moraines there are also areas with a hummocky ground moraine. Thaw depressions in the ground moraine area contain a system of shallow and small ponds.

#### ZONE WITH CREVASSE FEATURES, SUPRAGLACIAL AND ABLATION CONES

A system of crevasse features has been formed in the western forefield of the Linné Glacier. All they run meridionally in general, are 10—60 m long, 0.5—3.5 m high and 2—10 m wide at the base. Most of them have large slope gradients, equal 40—50°. Many features are

# STREFA MARGINALNA LODOWCA LINNEUSZA

## MARGINAL ZONE OF LINNÉ GLACIER

0 30 60 90 120 150m



Fig. 1. Morainial zone of the Linné Glacier

Strefa marginalna lodowca Linneusza

- |                                                               |                                                                              |                                                                                |                                                                   |                                                                                                |
|---------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| czołowe waly lodowo-morainowe<br>frontal ice-moraine ridges   | pole wyładów lodowcowych<br>smoothed surfaces                                | stożki supraglacialne i ablacyjne<br>supraglacial and ablation cones           | języki soliflukcyjne<br>solifluction tongue                       | bruzdy wytopiskowe w obrębie walców lodowo-morainowych<br>away furrows with ice-moraine ridges |
| wewnętrzne waly lodowo-morainowe<br>inside ice-moraine ridges | ceratki<br>cirques                                                           | równina limnoglacialna<br>limnoglacial plan                                    | nisze niwalne<br>river scars                                      | suche doliny<br>dry valleys                                                                    |
| boczne waly lodowo-morainowe<br>lateral ice-moraine ridges    | sandr intramarginalny<br>intramarginal outwash plain                         | terasy morskie z gruntami wielokątnymi<br>marine terraces with polygonal soils | moreny niwalne<br>nival moraine                                   | jeziora<br>lakes                                                                               |
| morena powierzchniowa<br>surface moraine                      | sandr marginalny<br>marginal outwash plain                                   | doliny marginalne<br>marginal valleys                                          | przełomy obecnie funkcjonujące<br>now existing crossings          | rzeki<br>rivers                                                                                |
| morena denna falista<br>ground wavy moraine                   | ślady koryt rzecznych na sandrze<br>marks of the river-beds on outwash plain | karbońskie grzbiety<br>carboniferous ridges                                    | stare przełomy wód glacialnych<br>old crossings of glacial waters | zagłębienia wytopiskowe<br>melting basin                                                       |
| morena denna płaska<br>ground flat moraine                    | formy szczytowe /ozy, kony/<br>fuskers, kames                                | nisze osuwiskowe<br>slide scars                                                |                                                                   |                                                                                                |



intensively undermined by marginal streams present in this zone. Their inner structure is varying but there are also some common attributes. At the bottom of the exposures there is usually a relic ice with a ground moraine, and above with an inner moraine melted into the ice. The relic ice is overlain by stratified glacialfluvial deposit of varying thickness. These strata are deformed in places where the sediments slid on the melting ice (Phot. 5).

An esker is the most typical feature. It occurs within the ice-dam lake that fills the central basin of the morainal zone in front of the glacier snout. This esker is the elongated feature (60 m long and maximum to 9 m wide). In the inner structure there is a fine and usually well sorted mineral matter with its layers dipping to the north (Ryżyk 1981). A locally deformed bedding should be connected with the undermining of the esker by lake waters and with a subsidence of its marginal fragments, makes a definite classification of the esker into supraglacial or subglacial features impossible. At the surface of this form, similarly as in the case of two others, some very fine pebbles were found. Their origin is to be connected with the earlier marine transgression in this part of the valley. Afterwards they were transported by the glacier and then, deposited by its waters as glacialfluvial deposits.

Similar features as in the morainal zone of the Linné Glacier, were studied among others by Szupryczyński (1963): the glacier Gas, Bunge, Werenskiöld, Nann, Torell and Klimaszewski (1960) the Comfortless Glacier in Spitsbergen.

In the frontal zone of the Linnébreen there are also supraglacial and ablation cones. They are the common features noted on glaciers of Spitsbergen or Iceland (Kozarski, Szupryczyński 1978). Supraglacial covers and cones are composed of glacialfluvial sediment of varying roundness and distinct stratification. It covers a glacial or relic ice. Due to ice melting and erosion of supraglacial and lateral streams, such features are destructed in a short time. Long axes of ablation cones are parallel to the long axis of the glacier (Phot. 2). It results from such orientation of shear planes, at which a concentration of a mineral sediment occurs. A formation of these features is also the effect of the action by supraglacial streams that deposit some mineral sediment in canals or crevasses of the glacier. Already a very thin such insulating layer favours the development of ablation cones. According to Kozarski and Szupryczyński (1978) they are quickly destructed due to gravitative transport of the sediment. In such case, there is a moment when the rest of the sediment at the sone summit is already too small to conserve sufficiently the underlying ice.

#### INTRAMORAINAL OUTWASH

In front of the snout of the Linnébreen there is a shallow ice-dam lake that changes its area with the varying water inflow. During a dry and cloudy weather the water level in this lake drops 1.1–1.2 m. It is fed by numerous lateral and supraglacial streams that form outwash fans. Outwash sediment in the proximal zone (mainly coarse

gravels) is 1—1.5 m thick whereas in the middle part its thickness decreases to 0.6—0.8 m (sands and fine gravel). A distal part of the outwash ends in the ice-dam lake by a delta, composed mainly of silts and fine sand. A thickness of this series reaches 40 cm and it spreads on a ground moraine. Fan-like outwash layers dip northerly at the angle to 18°.

#### EXTRAMORAINAL OUTWASH

In the foreland of the terminal moraine there is the extramorainal outwash that can be named, after Bogucki (1976), the outwash plain as it has been formed similarly as the outwash of the Skeidararjökull in Iceland, by superimposed fans and deltas and their lateral accretion. The root of this outwash is composed of mineral non-stratified sediment with numerous blocks to 1.2 m in diameter (Phot. 3). Proximal slopes of this feature are inclined at an angle of 3—4°. In the middle part the outwash cone is fan-shaped wider and its distal part contacts with smaller morainal cones that have their roots at the foot of the Kalkegga and Agaardtoppen massifs (Phot. 6). A slope inclination decreases to 2° and the sediment is considerably finer: usually well stratified sandsand gravels. In some places there are already small stone polygons. The surface of higher outwash fragments is overgrown by tussocks of saxifrages as well as by mosses and lichens.

#### DEVELOPMENT PHASES OF THE MORAINAL ZONE

Three gorges drained the whole morainal zone when the Linné Glacier snout reached the lowest parts of the proximal slopes of the outer ice-cored moraine. Now only one of these gorges is active (Phot. 3). The first deglaciation phase was expressed by a frontal retreat. Buried blocks of glacial ice occurred locally only as proved by thaw lakes. Change of the retreat rate resulted in a formation of a distinct ice-cored moraine inside the morainal zone. The glacier must have stagnated there for a couple of years. The morainal zone was drained in that time through 5 or 6 gorges in the inner moraine and the ice-dam lake was formed between both moraines. After the lake was drained, a distinct depression in the morainal zone and a small limnoglacial plain was formed. The further retreat of the glacier was fully a frontal one as little relic ice and thin beds only of ground and ablation moraine occur. Locally even bedrock outcrops are noted. This deglaciation enabled finally a development of the ice-dam lake, with the intramorainal outwash inside formed by lateral streams. When the ice-dam lake between the outer and inner moraines was drained, then the waters from the whole zone started to flow through a single gorge only.

During the glacier retreat in the recent years, its forefield was found to be covered by crevasse features, cones and supraglacial planes. A retreat of the glacier is proved not only by a removal of its snout but also by lowering of the surface and lateral shrinkage. The surface lowe-

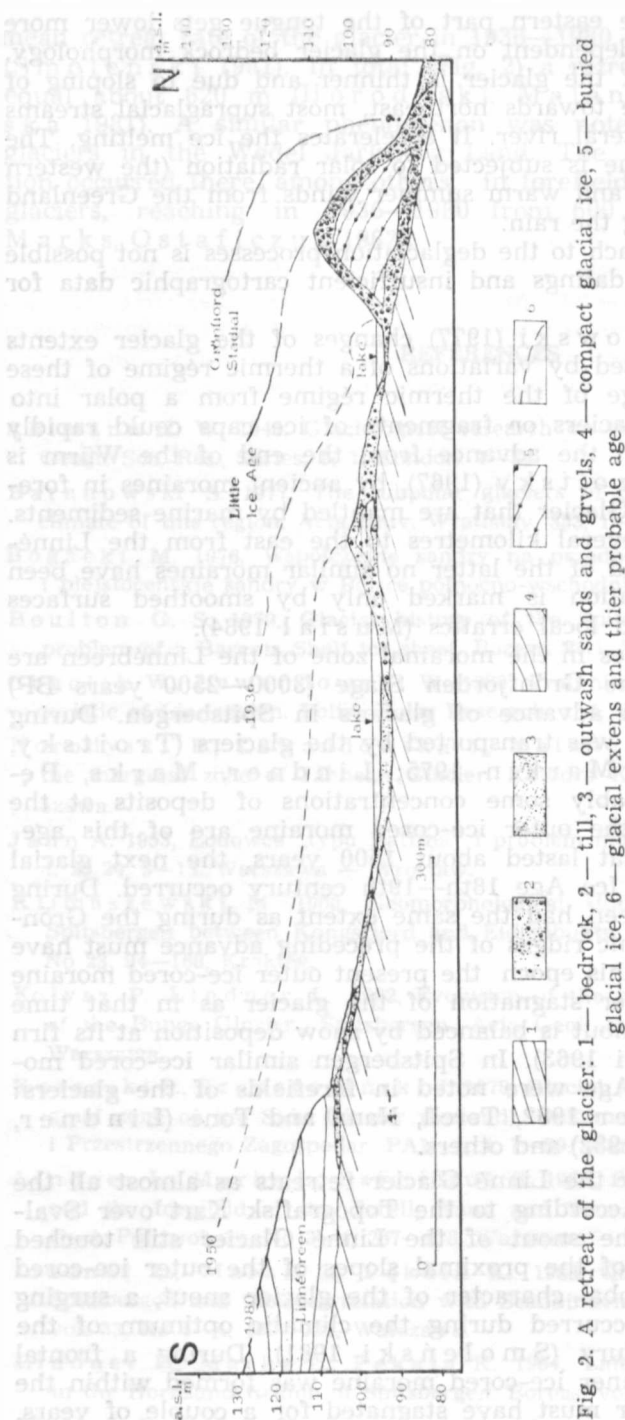


Fig. 2. A retreat of the glacier: 1 — bedrock, 2 — till, 3 — outwash sands and gravels, 4 — compact glacial ice, 5 — buried glacial ice, 6 — glacial extens and thier probable age

Recesja lodowca: 1 — podłoże skalne, 2 — glina morenowa, 3 — wymyte piaski i żwir, 4 — zbiły lód z lodowca, 5 — lód wykopany z lodowca, 6 — rozmiary lodowca i jego prawdopodobny wiek



ring is not uniform. The eastern part of the tongue gets lower more quickly what is highly dependent on the glacier bedrock morphology. The western fragment of the glacier is thinner and due to sloping of the whole glacier surface towards northeast, most supraglacial streams flow into the eastern lateral river. It accelerates the ice melting. The eastern part of the tongue is subjected to solar radiation (the western part remains in shadow) and warm summer winds from the Greenland Sea, that frequently bring the rain.

A chronological approach to the deglaciation processes is not possible due to lack of absolute datings and insufficient cartographic data for comparative purposes.

According to Baranowski (1977) changes of the glacier extents have been primarily caused by variations of a thermic régime of these glaciers. During a change of the thermic régime from a polar into a subpolar one, some glaciers or fragments of ice caps could rapidly advance (as surges). Such the advance from the end of the Würm is indicated, according to Troitsky (1967), by ancient moraines in forefield of the Grönfjorden Glacier that are mantled by marine sediments. This glacier is located several kilometres to the east from the Linnébreen. But in the forefield of the latter no similar moraines have been noted. The Würm glaciation is marked only by smoothed surfaces (Fig. 1), glacial striae and local erratics (Musiał 1984).

Outer terminal moraines in the morainal zone of the Linnébreen are of the Holocene age. The Grönfjorden Stage (3000—2500 years BP) was the first post-Würm advance of glaciers in Spitsbergen. During this advance much debris was transported by the glaciers (Troitsky, Zinger, Koryakin, Markin 1975; Lindner, Marks, Pękala, 1983, 1984). Probably some concentrations of deposits at the foot of distal slopes of the outer ice-cored moraine are of this age. After a retreat phase that lasted about 1500 years, the next glacial episode named the Little Ice Age 18th—19th century occurred. During this advance the Linnébreen had the same extent as during the Grönfjorden Stage. The morainic ridges of the preceding advance must have been remodelled. During this epoch the present outer ice-cored moraine was formed after a longer stagnation of the glacier as in that time the ablation at a glacier snout is balanced by snow deposition at its firn field (Szupryczyński 1963). In Spitsbergen similar ice-cored moraines of the Little Ice Age were noted in forefields of the glaciers: Bunge (Kłysz, Lindner 1982, Torell, Nann and Tone (Lindner, Marks, Ostaficzuk 1982) and others.

Since the 19th century the Linné Glacier retreats as almost all the glaciers in Spitsbergen. According to the Topografisk Kart over Svalbard 1:100 000 (1948), the snout of the Linné Glacier still touched in 1936 the lowest parts of the proximal slopes of the outer ice-cored moraine. Basing on the lobal character of the glacier snout, a surging seems possible to have occurred during the climatic optimum of the thirties in the 20th century (Smoleński 1981). During a frontal deglaciation the second inner ice-cored moraine was formed within the morainal zone. The glacier must have stagnated for a couple of years, probably in 1948—1951. The data were received from evaluation of the

mean retreat rate of the glacier in 1936—1980, equal about 14 m a year (Smoleński 1981). In total (Fig. 2) a retreat during this time was equal about 620 m (Horodyski, Malanowski, Lewandowska 1981). A similar phenomenon was noted in forefields of some glaciers in the Wedel Jarlsberg Land. The most extensive deglaciation occurred there, among others, in forefields of the Torell and Nann glaciers, reaching in 1936—1980 from 600 to 1000 m (Lindner, Marks, Ostaficzuk 1982).

#### REFERENCES

- Ahlmann H. W. 1948, Glaciological research on the North Atlantic coast. Roy. Geogr. Soc. Res., Series, N 1, London. 1—82.
- Baranowski S. 1977, The subpolar glaciers of Spitsbergen, seen against the climate of this region. Acta Univ. Wratislav. 393, 1—157, Wrocław.
- Bogacki M. 1976, Współczesne sandry na przedpolu Skeidararjökull (Iceland) i plejstoceńskie sandry w Polsce północno-wschodniej. Rozprawy UW. Warszawa.
- Boulton G. S. 1979, Glacial history of the Spitsbergen Archipelago and the problem of a Barents Shelf ice sheet. Boreas. 8(1). 31—58, Oslo.
- Gogołek W., Lewandowski W. 1980, Preliminary geomorphological characteristic of Linnedalen. Polish Polar Research. z. 4, Warszawa.
- Horodyski B., Lewandowska J., Malanowski T. 1981, The map of the marginal zone of Linnean Glacier. Katedra Kartografii WGiSR UW. Warszawa.
- Jahn A. 1953, Lodowce „typu Baffina” i problem moren ablacyjnych. Czas. Geogr. t. 23/24. 3—13. Warszawa — Wrocław.
- Klimaszewski M. 1960, Geomorphological studies of the western part of Spitsbergen between Kongsfjord and Eidembukta. Scient. Books of Jagel. Univ No 23, 94—168, Kraków.
- Kołyś P., Lindner L. 1982, Evolution of the marginal zone an the forefield of the Bunge Glacier., Spitsbergen. Acta Geol. Pol., vol. 32, No 3—4, 253—266, Warszawa.
- Kozarski S., Szupryczyński J. 1978, Glacial forms and deposits in the marginal zone of the Sidu Glacier (Iceland). Dokumentacja Geograf. Inst. Geograf. i Przestrzennego Zagospodar. PAN. z. 4. 1—59. Warszawa.
- Lindner L., Marks L., Ostaficzuk S. 1982, Evolution of the marginal zone and the forefield of the Torell, Nann and Tone glaciers in Spitsbergen. Acta Geol. Pol., vol. 32, No 3—4, 267—278, Warszawa.
- Lindner L., Marks L., Pękala K. 1983, Quaternary glaciations of South Spitsbergen and their correlation with Scandinavian glaciations. Acta Geol. Pol., vol. 33, No 1—4, 169—182, Warszawa.
- Lindner L., Marks L., Pękala K. 1984, Late Quaternary glacial episodes in the Hornsund Region of Spitsbergen. Boreas, vol. 13, 35—47, Oslo.
- Møller J. T. 1960, Glaciers and periglacial phenomena in the Upernivik Island. West Greenland. Abstr. of Papers, International Geogr. Congress.

- Musiał A. 1981, Badania geomorfologiczne w NW części Ziemi Nordenskiölda (Spitsbergen Zachodni). Materiały studenckiej sesji polarnej KNSG WGiSR UW. 19—30. Warszawa.
- Musiał A. 1983, Erratics in the north-west part of Nordenskiöld Land. Polskie badania polarne 1970—1982, Rozprawy UMK. 150—155. Toruń.
- Musiał A. 1984, Ancient glaciations in the north-western part of Nordenskiöld Land and their extent in the light of characteristic occurrence of erratics. *Miscellanea Geographica* 57—65, Warszawa.
- Nordenskiöld Land-Touring map. 1:200 000. 1979. Norsk Polarinstitut. Oslo.
- Ryżyk E. 1981, Charakterystyka geomorfologiczna marginalnej strefy Lodowca Linneusza. Materiały studen. sesji polarnej KNSG WGiSR UW. 31—40. Warszawa.
- Ryżyk E. 1983, Rzeźba strefy marginalnej Lodowca Linneusza na Spitsbergenie Zachodnim. Praca magisterska. Zakład Geomorfologii WGiSR UW, 1—60, Warszawa.
- Schytt V. 1956, Lateral drainage channels along the northern side of the Molke Glacier, North-West Greenland. *Geogr. Ann.*, vol. 38, Stockholm, 64—77.
- Smoleński W. 1981, Ogólna charakterystyka Lodowca Linneusza. Materiały studenckiej sesji polarnej, KNSG WGiSR UW, 41-54, Warszawa.
- Shumskiy P. 1949, Sovremennoye oledyeniye Sovetskoy Arktiki. *Trudy Arkticheskogo Instituta*, t. 11.
- Szupryczyński J. 1963, Relief of marginal zone of glaciers and types of deglaciation of southern Spitsbergen glaciers. *Prace Geogr. IG PAN*, No 39, 1—162 Warszawa.
- Szupryczyński J. 1968, Some problems of the Quaternary on Spitsbergen. *Prace Geogr. IG PAN* No 71, 1—128, Warszawa.
- Topografisk Kart over Svalbard 1:100 000. 1948, Bald B-10. Van Mijenfiord Norges Svalbard. Oslo.
- Troitsky L. S., 1967, Glacieomorfologicheskije issledovaniya na Shpitsbergienie. *Matier. glacyol. issled. Khronika, obsuzhdeniya*, wyp. 13. Moskwa.
- Troitsky L. S., Zingier J. M., Koryakin W. S., Markin Michalew W. J. 1975, Oledinienije Shpitsbergiena (Svalbarda). *Izd. Nauka*, 1-271. Moskwa.
- Word W. H. 1952, The physics of deglaciation of central Baffin Island. *Jour. of Glaciol.* vol. 2.

#### EXPLANATION OF PHOTOGRAPHS

Phot. 1. General sight of the Linnébreen from the eastern ice-cored moraine (photo by T. Malanowski).

Phot. 2. Flat snout of the Linné Glacier with ablation cones, median and surface moraines (photo by T. Malanowski).

Phot. 3. Gorge in the outer ice-cored moraine. Relic ice is conserved by a glacial debris (photo by T. Malanowski).

Phot. 4. Natural exposure in a ground moraine of the glacier forefield (photo by E. Ryżyk).

Phot. 5. Crevasse features in the forefield of the Linné Glacier (photo by E. Ryżyk).

Phot. 6. Central part of the extramorainial outwash. A distal part contacts with outwash fans of the glaciers formed on eastern slopes of the Aagaardtoppen (photo by T. Malanowski).

Phot. 7. Exposure in the outer terminal ice-cored moraine. Layers of relic ice are interbedded with a mineral debris of the inner moraine and dip northwards (photo by E. Ryżyk).

### STRESZCZENIE

Scharakteryzowano lodowiec Linneusza (Linnébreen) występujący na Ziemi Nordenskiölda oraz jego strefę marginalną. Przeprowadzono analizę rzeźby, osadów i procesów występujących w obrębie tej strefy. Na podstawie tych obserwacji oraz materiałów kartograficznych scharakteryzowano kolejne etapy jej rozwoju. Wykonano mapę geomorfologiczną oraz dokumentację fotograficzną. Lodowiec Linneusza podczas trwania obserwacji (latem 1980 r.) nie wykazywał żadnego ruchu, był więc martwy. Zaliczamy go do podtypu dolinnego w grupie lodowców górskich.

Na obszarze strefy marginalnej Linnébreen stwierdzono występowanie dwóch czołowych wałów lodowo-morenowych oraz bocznych. W swej budowie wewnętrznej mają one zakonserwowane lodowe jądra z moreną wewnętrzną. W zewnętrznym wale czołowym stwierdzono rzadko spotykany układ płaszczyzn ślizgu, które są nachylone w kierunku dawnego ruchu lodowca (ku N). Sytuację tę należy tłumaczyć budową skalnego podłoża strefy marginalnej. Zjawiskiem często występującym na stokach proksymalnych bocznych wałów lodowo-morenowych są procesy spływowe, które prowadzą do szybszego topnienia lodu relikтового. Po zupełnym wytopieniu się lodu relikтового najprawdopodobniej utworzy się tam inwersyjna rzeźba pagórkowato-grzędowa. W obrębie strefy marginalnej występują ponadto obszary z moreną denną oraz zespół form szczelinowych. Formy te tworzą charakterystyczny krajobraz związany z recesją lodowca. Z deglacją związane też jest jezioro zaporowe oraz kończący się w nim delta stożek sandru intramarginalnego. Na przedpolu moren czołowych występuje sandr ekstramarginalny, który tworzy z innymi stożkami doliny równinę sandrową. W okresie 1936—1980 deglacją wyniosła 620 m, co daje przeciętną recesji ok. 14 m na rok.

### OBJAŚNIENIA FOTOGRAFII

Fot. 1. Ogólny widok na Linnébreen ze wschodniego wału lodowo-morenowego (fot. T. Malanowski).

Fot. 2. Płaskie czoło lodowca Linneusza ze stożkami ablacyjnymi, moreną środkową i powierzchnią (fot. T. Malanowski).

Fot. 3. Przełom w zewnętrznym wale lodowo-morenowym. Widoczny jest lód reliktowy zakonserwowany warstwą materiału mineralnego (fot. T. Malanowski).

Fot. 4. Naturalna odkrywka w morenie dennej na przedpolu lodowca (fot. E. Ryżyk).

Fot. 5. Formy szczelinowe na przedpolu lodowca Linneusza (fot. E. Ryżyk).

Fot. 6. Środkowa część sandru ekstramarginalnego. Część dystalna łączy się ze stożkami sandrowymi lodowców powstałych na wschodnich zboczach Agaardtoppen (fot. T. Malanowski).

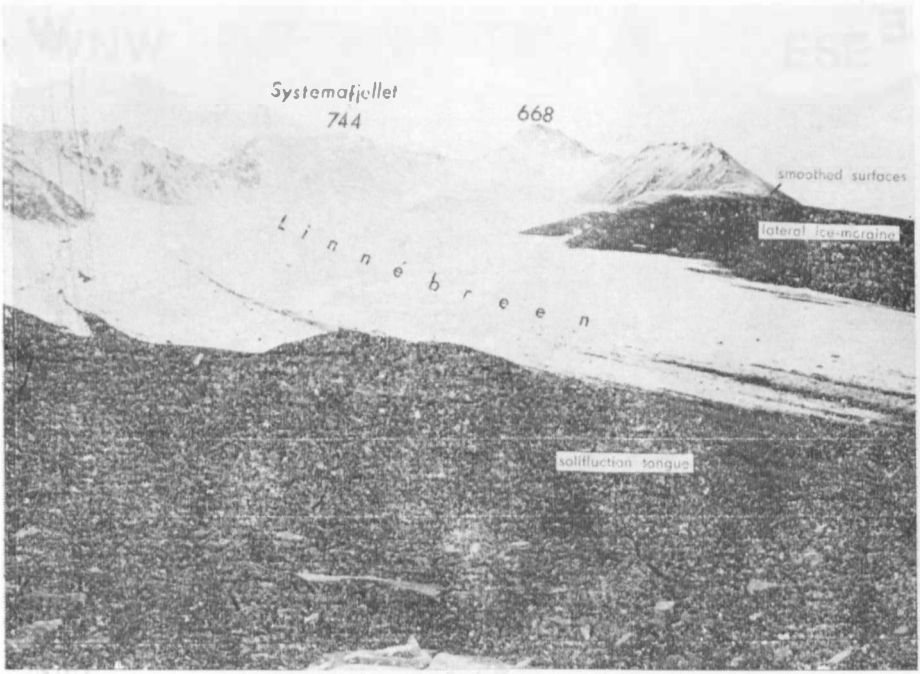
Fot. 7. Odsłonięcie w zewnętrznym wale lodowo-morenowym. Pokłady lodu relikowego są przewarstwione materiałem mineralnym moreny wewnętrznej i nachylone w kierunku północnym (fot. E. Ryżyk).

## РЕЗЮМЕ

Охарактеризовано ледник Линнея находящийся на Земле Norgenskiölda и ее маргинальную зону. Проведено анализ рельефа, осадков и процессов заходящих в границах этой зоны. На основе этих наблюдений, а также картографических материалов охарактеризовано очередные этапы ее развития. Составлено геоморфологическую карту и фотографическую документацию. Ледник Линнея во время наблюдения летом 1980 года не проявил никакого движения, был он мертвый. Его зачисляем к долинному подтипу в группе горных ледников.

На территории маргинальной зоны обнаружено выступление двух лобных ледниково-мореновых и боковых валов. В своей внутренней структуре имеют они законсервированы ледниковые ядра с внутренней мореной. В наружном лобном вале определено редкострачающиеся площади скольжения, которые наклонены в направлении прежнего хода ледника (к N). Эту ситуацию следует объяснить строением скальной почвы маргинальной зоны. Часто встречающимся явлением на склонах проксимальных боковых ледниково-мореновых валов являются стоковые процессы, которые способствуют быстрому таянию реликтового льда. На месте целиком растаявшего реликтового льда правдоподобно создается инверсивный холмисто-грядовый рельеф. В пределах маргинальной зоны выступает также пространство с доньевой мореной, а также комплекс щелевых форм. Эти формы создают характеристический пейзаж, связанный с отступлением ледника. С угасанием оледенения связано также заградительное озеро и кончающийся в нем дельтой конус задрового интрамаргинального поля. На подступах лобных морен выступает экстрамаргинальное поле, которое с другими конусами долины создаст задровую равнину. В период от 1936 по 1980 гг. угасание оледенения равнялось 620 м, что отвечает около 14 м/год среднему отступлению.





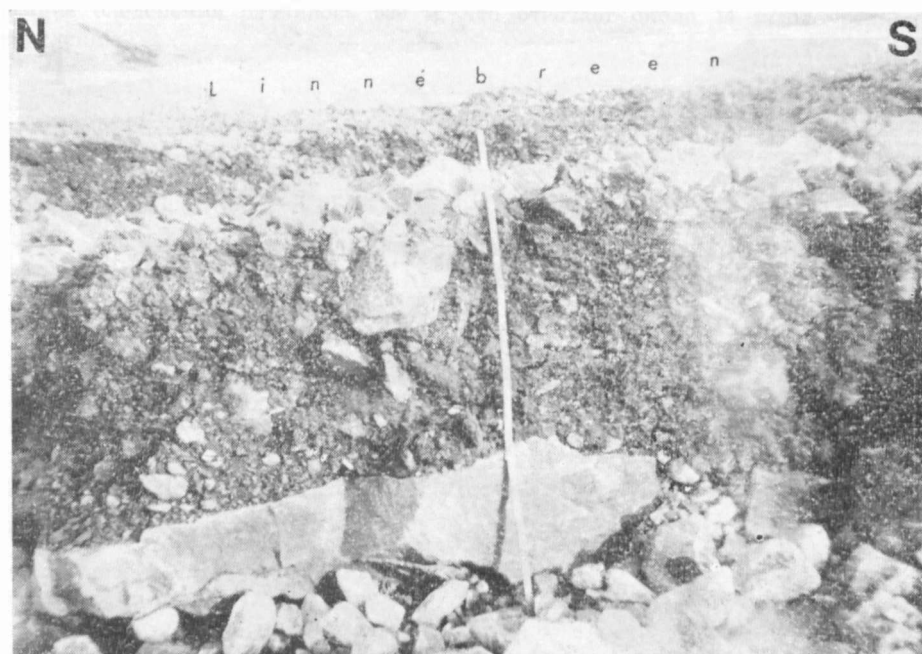
Fot. 1



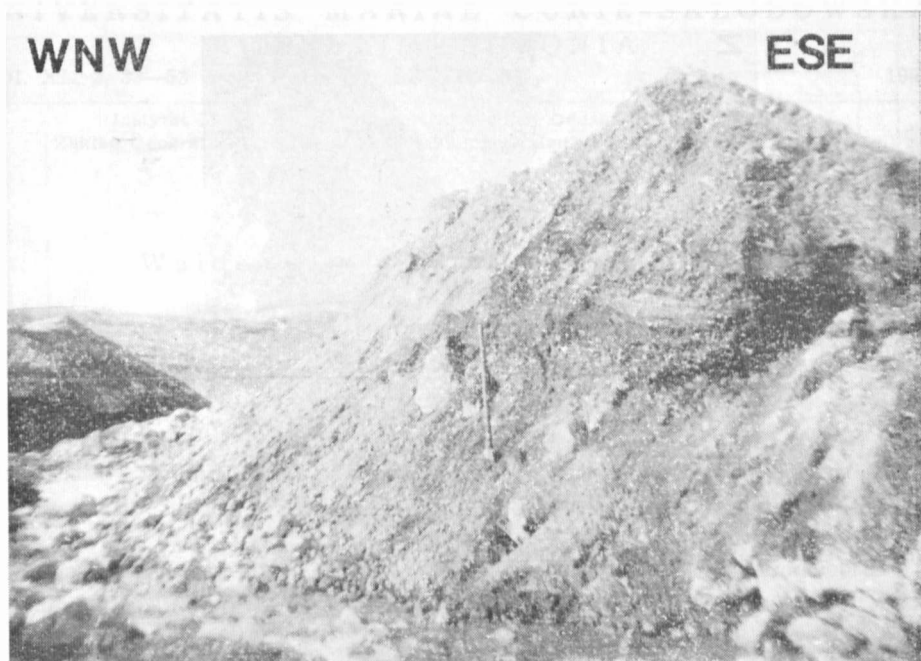
Fot. 2



Fot. 3



Fot. 4



Fot. 5



Fot. 6



Fot. 7